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E-WASTE IN BANGLADESH: UNDERSTANDING ITS CAUSES, IMPACTS, AND SUSTAINABLE MANAGEMENT STRATEGIES

Md. Mahamudur Rahman
Chief Architect, Environmentalist & Researcher, Eco Design Consultants Bangladesh (EDCBD).
E-mail: archmahamud@gmail.com

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ABSTRACT

The exponential growth of electronic consumption in Bangladesh, driven by increased urbanization, digitization, and consumer demand, has led to a significant rise in electronic waste (e-waste), posing serious environmental, health, and governance challenges. This paper presents a comprehensive literature review focused on identifying the causes, effects, and management benefits of e-waste within the socio-economic and environmental context of Bangladesh. E-waste is conceptually framed as a multidimensional problem, encompassing discarded electronic items such as computers, mobile phones, televisions, and household appliances that are either obsolete, non-functional, or no longer in use. These items, when improperly managed, release toxic substances like lead, mercury, and cadmium, contaminating soil, air, and water and severely affecting the health of informal workers and nearby communities.

The study operationalized the e-waste problem using key measurable indicators, including the volume and sources of e-waste, recycling practices, environmental contamination levels, health implications, and the effectiveness of existing policies and public awareness. A conceptual-operational matrix is constructed to guide future empirical studies and stakeholder-focused interventions. The circular recycling process is discussed in detail, outlining each stage—collection, transportation, dismantling, reuse, material recovery, safe disposal, and reintegration into production—based on principles of the circular economy. Through this lens, the paper emphasizes the importance of transitioning from the current linear, informal, and unregulated system to a formal, circular, and sustainable model.

Key recommendations are proposed to strengthen institutional capacity, enforce the E-Waste Management Rules, integrate the informal sector, expand e-waste infrastructure, raise public awareness, promote innovation and research, and foster regional and international collaboration. This review highlights the urgent need for a holistic, multi-stakeholder approach to e-waste management in Bangladesh.

Keywords: e-waste, technological impact, waste management, public health, economic risk, economic loses, urban waste, environmental pollution, waste of Bangladesh, air pollution, soil pollution, water pollution, technological waste, metal waste, health impact, economic impact,

I. INTRODUCTION

E-waste refers to discarded electrical or electronic devices which are obsolete, non-functional, or no longer wanted, and which may be destined for reuse, resale, recycling, or disposal. According to Bangladesh e-waste management rules 2021, e-waste means any electrical and electronic equipment as defined in Schedule I which has reached the end of its economic life or has ceased to be of use to the user or which has been discarded in the production process or discarded as unnecessary. The term **"electronic waste"**, commonly referred to as **"e-waste"**, encompasses discarded electrical or electronic devices that have reached the end of their useful life or are no longer wanted by their original users. This broad category includes a wide range of products such as mobile phones, computers, televisions, office equipment (e.g., printers, scanners), household appliances (e.g., refrigerators, air conditioners, microwaves), and other digital or electronic items [1].

E-waste is not limited to broken or malfunctioning devices; it also includes functional items that are obsolete, outdated, surplus, or no longer in demand due to rapid technological advancement or consumer preferences. These discarded electronics may be designated for reuse, resale, and refurbishment, recovery of valuable materials (such as gold, copper, and rare earth metals), recycling, or final disposal. Some of these products can be reconditioned and reintroduced into the market, thereby retaining some economic value [2]. However, a significant portion is categorized as non-recoverable waste, especially when devices are damaged beyond repair or when recovery is not economically viable [3]. In many cases, surplus electronics are mixed and un-segregated, making it difficult to differentiate between reusable and non-reusable items. As a result, environmentalists, policymakers, and researchers often use the umbrella term "e-waste" to refer to all forms of discarded electronic equipment, regardless of their potential for reuse or recycling. This term helps to underscore the urgency of developing efficient and sustainable systems for the collection, treatment, recycling, and safe disposal of such waste to prevent environmental contamination and health hazards [4].

Bangladesh generates a diverse range of waste types, each distinguished by its source, composition, and management practices. The annual total waste generation is estimated at between 25 and 30 million tons (250 to 300 million tons). Urban areas, especially Dhaka, Chittagong, Khulna, and Narayanganj, exhibit the highest waste generation rates. As of 2023, e-waste in Bangladesh is estimated at 300,000 tons per year, with projections indicating it could exceed 450,000 tons per year by 2025. Below is a summary of the various waste types generated in Bangladesh, along with their estimated percentages, primarily derived from urban waste management data. This information highlights the need for effective waste management strategies and initiatives to address these growing challenges. Table 01, presented below, illustrates the various categories of waste and their approximate percentages in Bangladesh.

The data presented herein are derived from information collected in urban areas, particularly in Dhaka and Chittagong. It is noteworthy that the volume of organic waste generated in rural areas is significantly higher, ranging from 75% to 80%. Moreover, hazardous waste and electronic waste are frequently disposed of improperly, leading to substantial environmental and health risks.

II. HISTORY OF E-WASTE DISPOSAL & MANAGEMENT

The history of electronic waste disposal began in the mid-1970s, marking a critical turning point in environmental regulations. With the passage of the Resource Conservation and Recovery Act (RCRA) in 1976, it became illegal to dump e-waste in the United States. The Basel Convention in 1989 further solidified this commitment by prohibiting the dumping of e-waste in less developed countries. As these laws took effect globally, it became imperative to develop innovative solutions for the proper disposal of electronic waste, leading to the establishment of effective and clean recycling practices for obsolete electronic equipment. In the 1980s, a series of high-profile international incidents prompted significant legislative changes concerning e-waste disposal. One notable case involved the Liberia-registered ship, Khian Sea, which was tasked with transporting 14,000 tons of incinerated e-waste ash from Philadelphia. Initially headed for New Jersey, the ship diverted southward when authorities refused to accept the waste, ultimately dumping 4,000 tons in the Caribbean and the remainder across various locations in Southeast Asia. This incident sparked widespread public outrage and directly contributed to the establishment of the Basel Convention, which laid down the foundation for safe e-waste disposal laws that remain in effect today. This transformation has propelled the recycling industry from a niche hobby to a robust and profitable sector. Since the Basel Convention, the demand for safe and efficient electronic waste disposal has fueled the growth of an entirely new industry dedicated to extracting reusable parts from discarded electronics. These components are then recycled for the benefit of local businesses, creating jobs for thousands around the globe. The work performed by electronic recycling companies has been pivotal in protecting local environments from significant harm, demonstrating the importance and impact of responsible e-waste management [6]. The detrimental effects of reckless e-waste disposal on the environment and human health became apparent, prompting early efforts to address the issue. The US government enacted RCRA, a landmark piece of legislation that laid the groundwork for managing hazardous waste, including e-waste [7]. The international community took action with the Basel Convention, which regulates the transboundary movement of hazardous wastes and their disposal [8]. The European Union implemented the Waste Electrical and Electronic Equipment (WEEE) Directive, making manufacturers responsible for managing their waste. [9] The concept of Extended Producer Responsibility (EPR) gained traction, requiring producers to take responsibility for managing e-waste generated from their products, including funding recycling costs.[10] Initiatives like the Global E-waste Statistics Partnership (GESP) emerged, collecting and sharing data on e-waste generation and management practices[11]. Research and development in areas like recycling technologies and the recovery of valuable resources from e-waste are ongoing. Bangladesh has also taken steps to regulate e-waste, including the Hazardous Waste (e-waste) Management Rules, 2021[12].

Table 01: Categories of waste and their amount in Bangladesh [5]

Types of Waste	Amount (%)	Main Sources of Generation
Organic Waste	65-70	Kitchen, food, fruits, vegetables
Plastic Waste	08-10	Packaging, water bottles, polythene
Paper Waste	05-07	Office, School, Shop
Metal Waste	02-03	Industry, Construction, E-waste
Glass Waste	01-02	Beverage bottles, tubes, windows
E-waste	01	Electronic products, mobiles, computers
Hazardous Waste	<01	Hospital, Lab, Battery
Clothing/textile waste	02-04	Garment industry, dyed cloth
Construction & Demolition Waste	04-06	Construction, demolished buildings, bricks, cement
Others (Ceramics, Rubber, Leather etc.)	01-02	Various small industries and households

III. CONCEPTUALIZATIONS & OPERATIONALIZATION OF THE PROBLEM

Conceptualizations

In the context of Bangladesh, the e-waste problem is a rapidly growing environmental and public health concern due to increased consumption of electronics, lack of proper disposal infrastructure, and dominance of informal recycling practices. Conceptually, the e-waste problem can be understood as a multidimensional issue encompassing environmental degradation through toxic emissions and soil and water contamination; human health hazards caused by exposure to hazardous materials such as lead, mercury, and cadmium; and socio-economic implications including child labor, unsafe working conditions, and loss of valuable materials due to inefficient recycling. Additionally, weak regulatory enforcement, limited public awareness, and absence of a formal collection and recycling system further exacerbate the challenge. Thus, the e-waste problem in Bangladesh reflects a complex interplay of technological, social, economic, and governance-related factors that require holistic understanding and sustainable intervention. A conceptual illustration of the idea is shown in Figure 01 below:

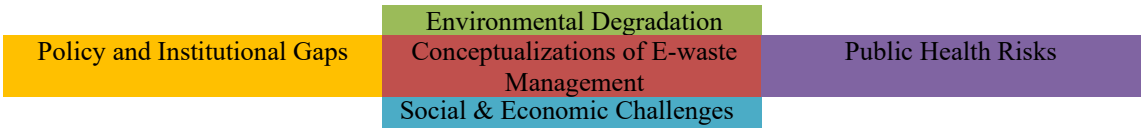

Figure 01: Conceptual Framework of e-waste Management

Operationalization

Operationalization is the process of turning abstract concepts into measurable variables or indicators for research. Below the operationalization of the problem e-waste are provided in the Table 02.

Table 02: Operational Metric of e-waste

No	Conceptual Variable	Operational Definitions / Indicators	Data Sources / Methods
1	**E-waste Generation**	Volume of e-waste generated annually (in tons); growth trends	Secondary data (DoE, UN reports, BTRC)
2	**Sources of E-waste**	% contribution from households, commercial sector, government offices, etc.	Surveys, interviews, sectoral reports
3	**Recycling Practices**	Share of e-waste processed formally vs. informally; types of recycling methods	Field observation, NGO/DoE reports
4	**Environmental Impact**	Heavy metal concentration in soil/water; air quality near recycling sites	Lab tests, environmental sampling
5	**Health Impact**	Common health symptoms (e.g., respiratory, skin issues) among workers	Interviews with recyclers; hospital records
6	**Economic Impact**	Estimated value of recoverable materials; income of informal workers	Expert interviews; valuation studies
7	**Policy & Regulation**	Existence and enforcement level of e-waste regulations (e.g., E-waste Rules 2021)	Policy analysis; interviews with officials
8	**Public Awareness**	% of population aware of e-waste hazards and proper disposal methods	Household surveys; awareness campaign reviews

IV. JUSTIFICATION OF THE RESEARCH

Bangladesh is experiencing rapid digitalization, urbanization, and economic growth, which has resulted in an alarming increase in electronic consumption and, consequently, e-waste generation. However, the country lacks an integrated and enforceable e-waste management framework, leading to severe environmental pollution, public health risks, and the loss of valuable resources. Informal recycling practices dominate the sector, exposing workers and surrounding communities to hazardous materials without any regulatory oversight.

V. OBJECTIVES

Broader Objective:

To critically analyze the underlying causes, environmental, social, economic impacts, and explore effective management approaches of electronic waste (e-waste) in Bangladesh.

Specific Objectives:

- To determined the types of e-waste in Bangladesh.
- To identify the causes of generating e-waste in Bangladesh.
- To examine the effect of e-waste in Bangladesh.
- To find-out the benefits of managing the e-waste in Bangladesh.

VI. LITERATURE REVIEW

This literature review highlights major global agreements on e-waste management, focusing on key international frameworks and treaties established to address the challenges of e-waste. It emphasizes their objectives, implementation strategies, and the collaborative efforts of nations to promote sustainable practices.

International Convention for the Prevention of Pollution from Ships (MARPOL) (73/78/97): The transportation of goods via ships falling under the MARPOL agreement has been associated with the release of hazardous substances into the air and water bodies, notably oil pollution and toxic liquids. The MARPOL agreement has, however, played a crucial role in mitigating the resultant pollution caused by international shipping. It is worth noting that the agreement has a far-reaching application, encompassing 99% of traders worldwide.[13].

Basel Convention on the Control of Tran's boundary Movements of Hazardous Wastes and their Disposal (1989): The main objective of the ***"BASEL CONVENTION"*** is to safeguard human health and the environment from the detrimental impact of hazardous waste. Its key components include efficient and responsible management of waste, ensuring proper disposal of waste and minimizing any negative impact on the environment and human health [14].

Montreal Protocol on Ozone Depleting Substances (1989): The Montreal Protocol is a globally recognized accord that has been implemented with the objective of mitigating the depletion of the ozone layer. The primary cause of this environmental issue is the emission of harmful substances such as hydro chlorofluorocarbons and chlorofluorocarbons. The protocol aims to control the production and consumption of these substances by setting limits and encouraging the use of alternative products. Since its inception, the protocol has proven to be an effective instrument in the protection of the ozone layer, and it continues to be a critical component of international environmental governance [15].

Organization for Economic Cooperation and Development, Council Decision Waste Agreement (1992): The Council pronouncement Waste Agreement aims to control and decrease the amount of waste that is exported for the purpose of improving materials. The target of the agreement is to decrease the negative impacts caused by the transboundary movement of hazardous waste [16].

United Nations Framework Convention on Climate Change (UNFCCC) (1994): The United Nations Framework Convention on Climate Change (UNFCCC) has been actively engaged in the conversion of toxic e-waste to green initiatives. This initiative involves the education and training of waste pickers across the country on the proper collection and disposal of electronic waste products, including computers, batteries, and mobile phones. This training is intended to equip these waste pickers with the necessary skills to responsibly recycle and dispose of e-waste products, thereby reducing the environmental impact of such waste. Through this initiative, the UNFCCC is demonstrating its commitment to promoting sustainable waste management practices and reducing the negative impact of e-waste on the environment [17].

Bamako Convention against Illicit Trafficking of Hazardous Wastes (1998): The Bamako Convention is a treaty of African nations prohibiting the import into Africa of any hazardous waste. The convention came into force in 1998. The convention is a response to Article 11 of the Basel Convention, which encourages parties to enter into bilateral, multilateral, and regional agreements on Hazardous Waste to help achieve the objectives of the convention. The impetus for the Bamako convention also arose from the failure of the Basel Convention to prohibit trade of hazardous waste to less developed countries and the realization that many developed nations were exporting toxic wastes to Africa [18].

Environmental Protection Agency (EPA): The mission of the EPA is to protect human health and the environment within the United States of America. In doing so, the organization has developed a very informative homepage that all parts of society can access and obtain accurate information sufficient to effectively participate in managing human health and environmental risks. EPA works very seriously on e-waste, and on its homepage, there are almost 130000 contributions related to e-waste handling [19].

The Global E-waste Statistics Partnership (GESP - 2017):

In 2017, the International Telecommunication Union (ITU), United Nations University – Sustainable Cycles (UNU-SCYCLE), and the International Solid Waste Association (ISWA) formed the Global E-waste Statistics Partnership to address e-waste management challenges. Since January 2022, Sustainable Cycles has been a program under the United Nations Institute for Training and Research (UNITAR), with the partnership now managed by ITU and UNITAR-SCYCLE. The GESP aims to monitor e-waste development, assist countries in producing e-waste statistics, and inform various stakeholders about global e-waste data to the Sustainable Development Goals (SDGs)[20]. Its goals include:

- Collecting and improving global e-waste statistics
- Enhancing understanding of e-waste data
- Improving data quality through national capacity building
- Raising awareness and communicating findings to the public and stakeholders.

United Nations E-waste Coalition 2019: Rapid innovation and declining costs have made electronic devices more accessible, causing e-waste to become the fastest-growing waste stream globally. By 2020, internet-connected devices were projected to reach 25–50 billion, significantly adding to the problem. In 2018 alone, e-waste amounted to 50 million tones, with only 20% properly managed, posing serious environmental and health risks, especially to vulnerable populations. Yet, this waste stream also represents a $62.5 billion annual economic opportunity. To address this, a shift from the harmful linear model to a sustainable circular economy is essential. Technologies like cloud computing and IoT can support this transition by reducing the need for primary resources. A collaborative effort involving designers, manufacturers, and policymakers is crucial to manage e-waste across the product lifecycle. Aligning e-waste strategies with global sustainability goals offers a pathway toward a more equitable and eco-friendly future [21].

Waigani Convention (2001): The convention, officially known as The Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes, started in 2001. It is inspired by the Basel Convention and focuses on managing hazardous and radioactive waste in the South Pacific region. This convention is special because it covers radioactive waste and includes each Party's Exclusive Economic Zone (200 nautical miles). It also ties in with the London Convention to prevent marine pollution from dumping waste. Its main goals are to reduce cross-border movement of hazardous waste, minimize harmful waste production in the Pacific, and ensure safe disposal practices for the environment [22].

WEEE Forum (2002): The WEEE Forum, established in 2002, is the largest global center for managing waste electrical and electronic equipment (WEEE). Representing 46 producer responsibility organizations, we focus on effective e-waste management and the principles of extended producer responsibility. Our mission is to lead in e-waste competence and promote circularity. We provide platforms and software tools for our members to benchmark operations and access crucial data,, all while striving for a sustainable future [23].

Bangladesh Hazardous Waste (E-Waste) Management Rules- 2021: Under the powers conferred by Section 20, read with Section 6(ga) of the Bangladesh Environment Protection Act, 1995 (Act No. 1 of 1995), the Government has framed the Hazardous Waste (E-Waste) Management Rules, 2021. This shall apply to persons engaged in the production, marketing, purchase, sale, import, export, and storage, storage for laboratory research, disposal, repair, processing, and transportation of electrical and electronic products specified in Schedule 1 of these rules or any other activities related thereto. If, nothing in these rules shall apply to radioactive waste regulated by the Bangladesh Atomic Energy Act, 2012 (Act No. 19 of 2012) [24].

VII. METHODOLOGY

The methodology for this study involves systematic approaches that analyzes the underlying causes, environmental, social, economic impacts, and explore effective management approaches of electronic waste (e-waste) in Bangladesh. The Methodological framework for preparing the paper is given in Figure 02.

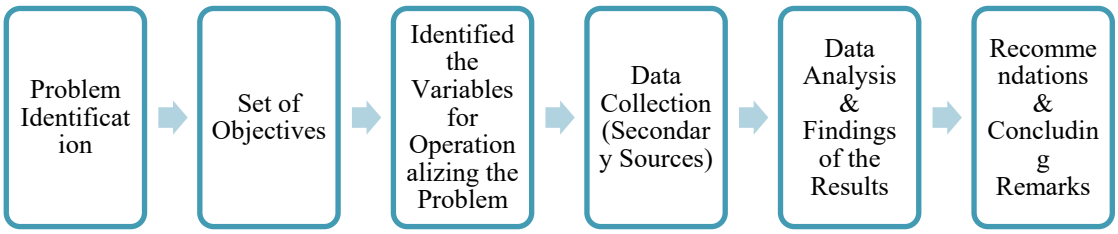
Problem Identification
Set of Objectives
Identified the Variables for Operationalizing the Problem
Data Collection (Secondary Sources)
Data Analysis & Findings of the Results
Recommendations & Concluding Remarks

Figure 02: Methodology of preparing the paper

Study Types: In this research endeavor, I will systematically gather data from a diverse range of secondary sources. Utilizing various analytical tools, I aim to meticulously examine this data to fulfill the specific objectives of this study.

Data Collection: The data collection process will encompass a broad spectrum of secondary sources, including scholarly books, peer-reviewed articles, and reputable online resources. This comprehensive approach will ensure a rich and varied dataset to support my research findings.

Data Sorting: Upon completion of the data collection phase, the gathered information will be thoughtfully organized and securely stored in a designated location. This structured approach will facilitate efficient data management and retrieval, ultimately enhancing the analysis process and aiding in achieving the study's objectives.

Data Analysis: The analysis of the collected data will involve the application of a variety of analytical tools and techniques, specifically tailored to interpret the insights derived from the secondary data sources. This analytical phase is crucial for synthesizing the information and drawing meaningful conclusions that align with the goals of the study.

VIII. FINDINGS

In 2022, Bangladesh generated a total of 367 million kilograms of electronic waste, resulting in a per capita generation rate of 2.2 kilograms. When comparing this statistic to those of Bangladesh's neighboring countries, distinct outcomes emerge. The statistics on total e-waste generation and per capita e-waste generation by neighborhood in Bangladesh are presented below in Chart 01 & Chart 02:

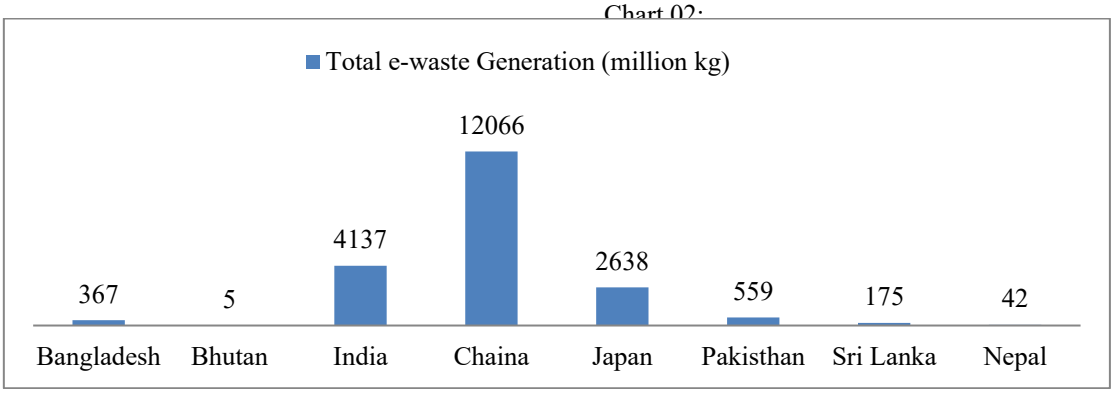

Chart 01: E-waste generation statistics by neighborhood country of Bangladesh (2022)

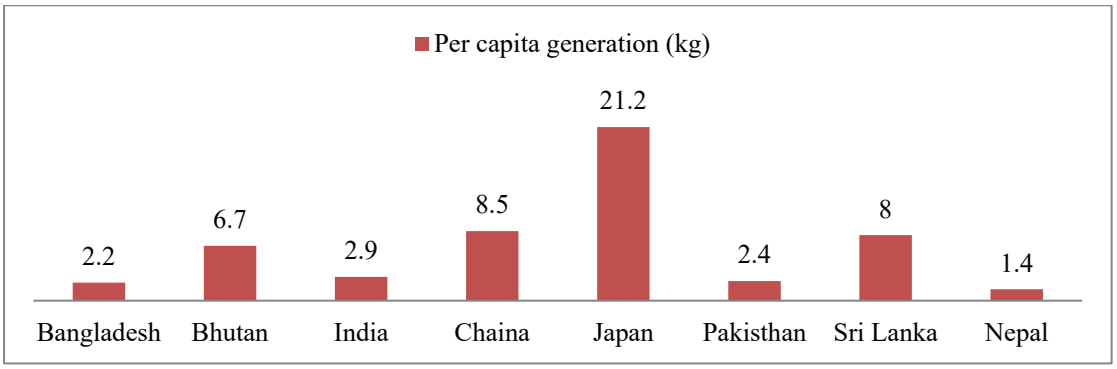

Chart 02: Per capita e-waste generates by neighborhood country of Bangladesh (2022)

The total e-waste generation among these neighboring countries exhibited significant variation. According to the analysis, Bangladesh's total e-waste generation of 367 million kilograms was considerably lower than that of larger economies such as India, China, and Japan; however, it surpassed the totals generated by Pakistan, Sri Lanka, Nepal, and Bhutan. An analysis of per capita e-waste generation in 2022 reveals that Bangladesh's per capita rate of 2.2 kilograms was lower than that of most of its neighboring countries (specifically India, China, Japan, Sri Lanka, and Bhutan), yet higher than that of Nepal. Notably, Japan recorded the highest per capita e-waste generation within this group at 21.2 kilograms.

In 2022, Asia produced the highest total e-waste generation at 13259 million kg, followed by Europe (9739 million kg) and America (9068 million kg). Africa generated 1640 million kg, while Oceania produced 452 million kg. In terms of per capita e-waste generation, America had the highest rate at 17.6 kg, followed by Europe (16.1 kg) and Oceania (13.3 kg). Asia's per capita generation was 2.5 kg, and Africa had the lowest at 1.6 kg, indicating that while Asia has the largest total e-waste, its per-person generation is much lower than in the other regions. Asia's large population likely contributes to its high total generation. The regional statistics pertaining to total e-waste generated, as well as per capita e-waste generation, are presented in Chart 03 & 04

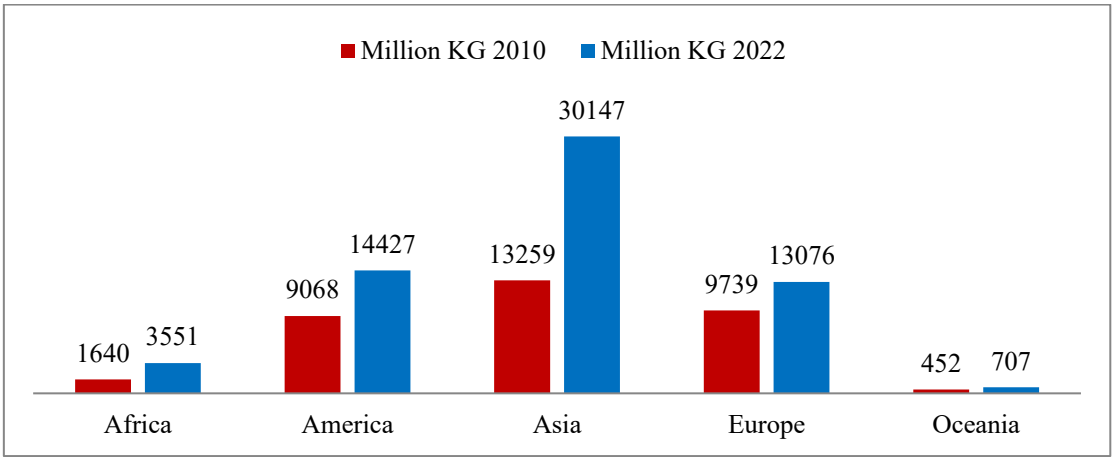

Chart 03: Region wise total e-waste generate (2022)

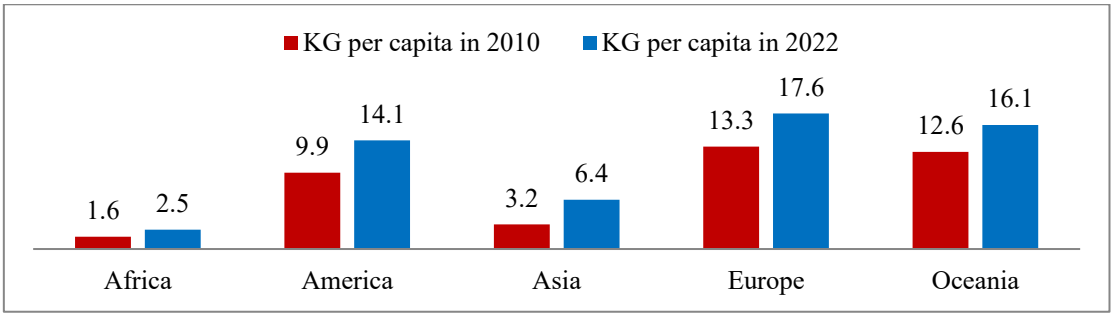

Chart 04: Per capita e-waste generate by region (2022)

In the present analysis, we examined the demographic characteristics of the regional population and discovered that the elevated population density in Asia correlates with a higher propensity for electronic waste generation. The following Chart 05 presents a detailed calculation of the regional inhabitants from 2010 to 2022.

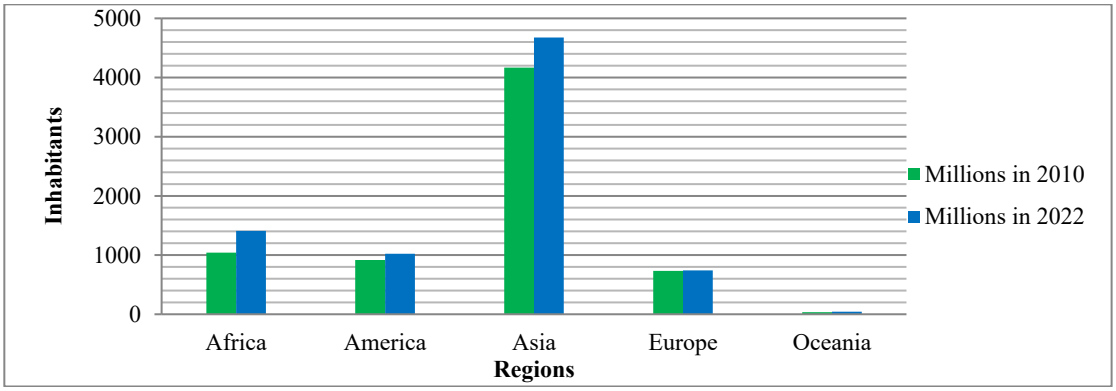

Chart 05: Regional Inhabitants

Regions with high total volumes face major systemic difficult conditions in managing the sheer amount of waste, regions with high per capita rates show bad conditions related to individual consumption habits contributing heavily to the problem. Regions with lower figures, particularly per capita, appear good in comparison from a waste volume perspective, but understanding the underlying socioeconomic factors is crucial for a complete picture.

Types of E-Waste

Electronic waste, or e-waste, encompasses discarded electrical and electronic devices that have reached the end of their useful life. This category includes a wide array of items, such as Household appliances, Monitoring and control instruments, Medical equipment, Automatic Machines, IT and telecommunication equipment, etc. While these items can contain valuable materials, such as gold and copper, they can also pose environmental and health risks due to toxic substances like lead and mercury. To address these challenges effectively, it is essential to focus on proper segregation and recycling practices. By doing so, we can not only minimize the adverse effects of e-waste but also promote a more sustainable approach to resource recovery and environmental protection.

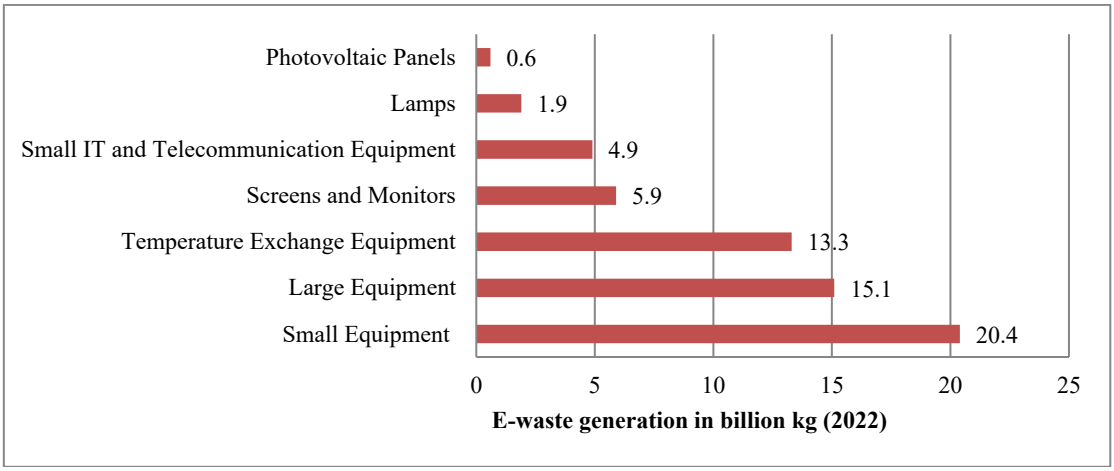

Chart 06: E-waste generation in billion kg (2022)

The chart 06 reveals key insights into global e-waste generation in 2022, highlighting that small equipment (20.4 billion kg) and large equipment (15.1 billion kg) are the main sources. This trend raises questions about product lifecycles and consumption patterns. Additionally, the significant amount of temperature exchange equipment (13.3 billion kg) emphasizes the need for studies on environmental impact and safe recycling. In contrast, lower volumes from photovoltaic panels (0.6 billion kg) and lamps (1.9 billion kg) indicate emerging waste streams with potential environmental risks. High volumes of IT and telecom equipment (4.9 billion kg) and screens/monitors (5.9 billion kg) suggest a need for innovation in material recovery, particularly for critical raw materials like rare earth elements.

Photo 01: Different sources of e-waste

When examining the metabolic rate of batteries, it becomes evident that a diverse array of batteries serves as the lifeblood for a wide range of electronic and technological products. Batteries contain toxic and hazardous materials like lead, cadmium, lithium, and mercury, which can pose significant environmental and health risks if not dispose of properly. Below is an insightful breakdown of the various types of batteries, highlighting their unique characteristics and specific applications:

Types of Battery & their uses

An overview of various types of batteries and their specific applications is presented in Table 03.

Types of Battery		Specific Applications
Primary (Single-Use) Batteries	**Alkaline Batteries**	▪ Common in household items (remotes, toys, flashlights) ▪ Contain zinc, manganese, and potassium hydroxide.
	Zinc-Carbon Batteries	▪ Used in low-drain devices like clocks and radios. ▪ Less expensive, shorter life.
	Lithium Primary Batteries	▪ Used in cameras, calculators, and watches. ▪ Contain lithium metal (very reactive).
Secondary (Rechargeable) Batteries	**Lead-Acid Batteries**	▪ Common in automobiles (car batteries), UPS systems. ▪ Contain lead and sulfuric acid (highly toxic).
	Nickel-Cadmium (Ni-Cd) Batteries	▪ Used in cordless tools, medical devices. ▪ Cadmium is highly toxic and carcinogenic.
	Nickel-Metal Hydride (Ni-MH) Batteries	▪ Found in rechargeable AA/AAA batteries, cameras. ▪ Less toxic than Ni-Cd, but still need proper disposal.
	Lithium-Ion (Li-ion) Batteries	▪ Used in mobile phones, laptops, EVs. ▪ Can catch fire if damaged; widely used and fast growing in e-waste volume.
	Lithium-Polymer (Li-Po) Batteries	▪ Found in drones, RC cars, smart phones, etc. ▪ Lightweight and powerful, but fire risk is high if punctured.
Button Cell Batteries		▪ Found in watches, hearing aids, and small electronics. ▪ May contain mercury, silver, or zinc-air compounds.

Table 03: Different types of batteries & their uses

Primary batteries like alkaline and lithium are common in household and small electronics, but contribute to waste. Rechargeable such as lead-acid, Ni-Cd, Ni-MH, Li-ion, and Li-Po power vehicles, tools, and devices, offering higher performance but posing fire and toxicity risks. Button cells, used in compact devices, may contain hazardous metals. Strategically, there is a critical need for safer designs, better recycling, and stricter regulation to address growing environmental and safety concerns.

IX. CAUSES OF GENERATING E-WASTE IN BANGLADESH

In addressing any issue, it is essential to accurately identify the underlying problem. To achieve this, an analysis of the root causes of electronic waste generation is conducted. This includes an examination of the primary cause and the subsequent secondary causes, which are effectively represented in the accompanying visual aid, Figure 03, below.

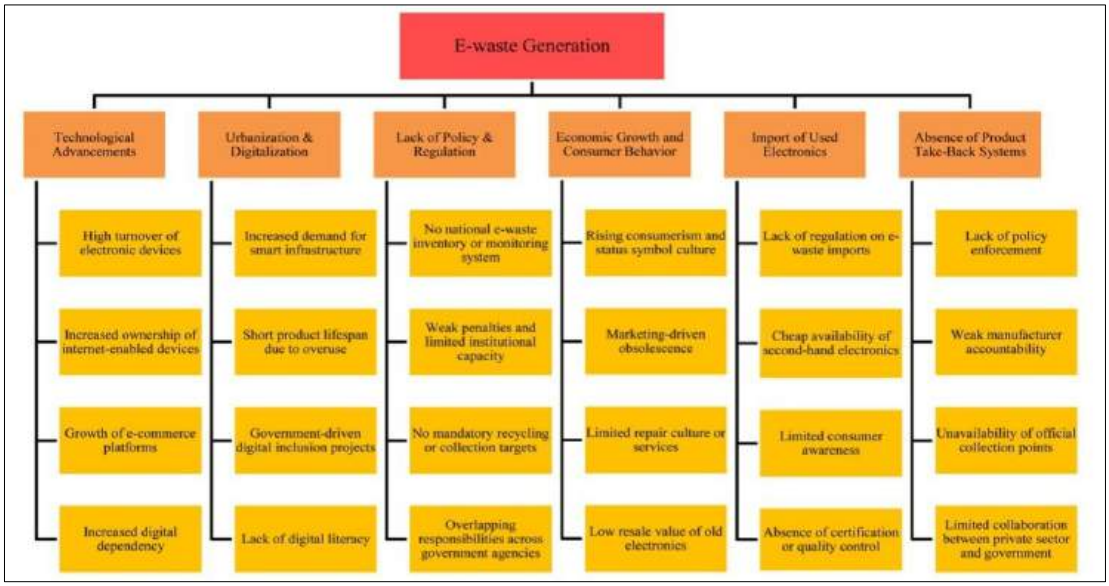
E-waste Generation
Technological Advancements
Urbanization & Digitalization
Lack of Policy & Regulation
Economic Growth and Consumer Behavior
Import of Used Electronics
Absence of Product Take-Back Systems
High turnover of electronic devices
Increased ownership of internet-enabled devices
Growth of e-commerce platforms
Increased digital dependency
Increased demand for smart infrastructure
Short product lifespan due to overuse
Government-driven digital inclusion projects
Lack of digital literacy
No national e-waste inventory or monitoring system
Weak penalties and limited institutional capacity
No mandatory recycling or collection targets
Overlapping responsibilities across government agencies
Rising consumerism and status symbol culture
Marketing-driven obsolescence
Limited repair culture or services
Low resale value of old electronics
Lack of regulation on e-waste imports
Cheap availability of second-hand electronics
Limited consumer awareness
Absence of certification or quality control
Lack of policy enforcement
Weak manufacturer accountability
Unavailability of official collection points
Limited collaboration between private sector and government

Figure 03: Causes of e-waste generation in Bangladesh

The primary & secondary contributors to the generation of e-waste can be outlined as follows:

Rapid Technological Advancements and Increased Internet Access: The continuous development of new technologies and the widespread availability of internet services have significantly accelerated the consumption and disposal of electronic devices. As newer models with advanced features are introduced frequently, older devices become obsolete more quickly, leading to increased electronic waste generation.

High turnover of electronic devices: due to frequent innovation in smart phones, computers, and smart appliances.

Increased ownership of internet-enabled devices: (e.g., routers, modems, smart TVs) which adds to household e-waste volume.

Growth of e-commerce platforms: accelerates access to and impulse purchases of electronics.

Increased digital dependency: (e.g., online education, remote work, streaming) leading to faster wear-and-tear of devices.

Lake of Policy & Regulation: Effective policies and regulatory frameworks are crucial to address e-waste in Bangladesh. The e-waste management regulations introduced in 2021 are a positive step, but e-waste continues to grow in the absence of improved institutional capacity and coordination to improve enforcement. Lack of implementation of mandatory take-back schemes, recycling targets, and producer responsibility obligations does not increase accountability of manufacturers and importers. However, these steps, if taken, will provide safe disposal options for consumers and help mitigate the e-waste crisis.

No national e-waste inventory or monitoring system: resulting in poor data for planning and enforcement.

Weak penalties and limited institutional capacity: to regulate illegal e-waste dumping and informal recycling.

No mandatory recycling or collection targets: for producers, distributors, or importers.

Overlapping responsibilities across government agencies: leading to poor coordination and implementation.

Rapid Urbanization and Digitalization: With increased urbanization and digital inclusion policies such as "Digital Bangladesh," access to electronic devices has become widespread across socio-economic classes. Government initiatives to distribute tablets, smart phones, and computers have increased the use and eventual disposal of electronics.

Increased demand for smart infrastructure: in urban centers (e.g., smart homes, surveillance, and smart transport) increases electronic device dependency.

Short product lifespan due to overuse: in high-density urban areas (e.g., mobile devices used intensively for work and communication).

Government-driven digital inclusion projects: (e.g., e-learning tools, public kiosks) that are not accompanied by end-of-life management plans.

Lack of digital literacy: among new user's leads to frequent device damage and quicker turnover.

Economic Growth and Consumer Behavior: Rising incomes and decreasing costs of electronic goods have led to increased consumption. The trend of upgrading devices more frequently, influenced by branding and obsolescence, has contributed to premature disposal.

Rising consumerism and status symbol culture: electronics viewed as status items encourage frequent replacement before end-of-life.

Marketing-driven obsolescence: companies release frequent model upgrades, pushing users to abandon functioning older models.

Limited repair culture or services: consumers often discard products instead of repairing them due to lack of technical services or affordability.

Low resale value of old electronics: discouraging reuse or second-hand circulation.

Import of Used Electronics: Bangladesh has become a major recipient of second-hand electronics, especially from developed countries. These imported devices often have short lifespan and are discarded within a short time, significantly increasing the volume of e-waste.

Lack of regulation on e-waste imports allows entry of near-end-of-life or damaged goods.

Cheap availability of second-hand electronics: drives informal markets that cannot offer warranties or repair options.

Limited consumer awareness: regarding the lifespan and risks of used imported devices.

Absence of certification or quality control: for imported second-hand goods, leading to faster breakdowns and disposal.

Absence of Product Take-Back Systems: There is a lack of Extended Producer Responsibility (EPR) mechanisms that oblige manufacturers or importers to collect and recycle products after end-of-life, leading to a linear rather than circular lifecycle.

Lack of policy enforcement: regarding Extended Producer Responsibility (EPR) even when rules exist.

Weak manufacturer accountability: producers/importers are not legally or financially responsible for post-consumer waste.

Unavailability of official collection points: for consumers to return old electronics.

Limited collaboration between private sector and government: for developing circular economy frameworks.

X. IMPACES OF E-WASTE IN DIFFERENT SECTORS

Impacts on Environment:

The rapid turnover of consumer electronics has contributed to a significant increase in the accumulation of electronic waste, particularly within developing nations, where improper disposal methods present serious environmental and public health hazards. Hazardous substances such as lead, mercury, and cadmium have the potential to leach into soil and groundwater, thereby contaminating essential water resources and entering the food chain, which ultimately creates profound environmental challenges. In certain areas, e-waste is incinerated in open spaces to recover valuable materials, resulting in the release of harmful pollutants into the atmosphere. To address these issues effectively, it is imperative that governments, manufacturers, and consumers collectively advocate for responsible recycling practices, embrace circular design principles, and implement stricter regulations governing e-waste. Sustainable disposal methods and the concept of extended producer responsibility are vital for mitigating the environmental impact associated with electronic waste.

Impacts on Health:

The improper disposal of electronic waste presents significant health risks due to the release of hazardous substances such as lead, mercury, cadmium, and brominates flame-retardants. These toxic chemicals can leach into the soil and water, or be released into the air via unsafe recycling practices, including open burning. The exposure to these toxins is directly linked to a variety of serious health issues, such as neurological damage, respiratory problems, kidney and liver dysfunction, and developmental disorders in children. Inhaling fumes or coming into contact with contaminated materials can lead to chronic health conditions and, in some instances, cancer. Vulnerable populations, especially children and workers in informal e-waste processing sectors in developing countries, face heightened risks due to prolonged exposure and inadequate protective measures. To effectively address these health impacts, it is essential to implement stricter regulations, adopt safer recycling methods, and enhance public awareness.

Impacts on Economy:

In 2022, global e-waste reached 31 billion kg, with 19 billion kg recovered. Iron had the highest recovery rates, while zinc and lead lagged. Approximately 300,000 kg of precious metals could also be recovered. Improper e-waste management leads to lost materials, increased reliance on virgin resources, and environmental harm, while effective recycling can drive economic growth and job creation. Informal practices in developing countries pose serious health risks. The e-waste sector recovered about USD 28 billion in metals but faced a net loss of USD 37 billion due to improper disposal. The total metal value in e-waste was USD 91 billion, primarily from copper, gold, and iron, yet global collection rates remained only 22.3%, hindered by informal recycling.

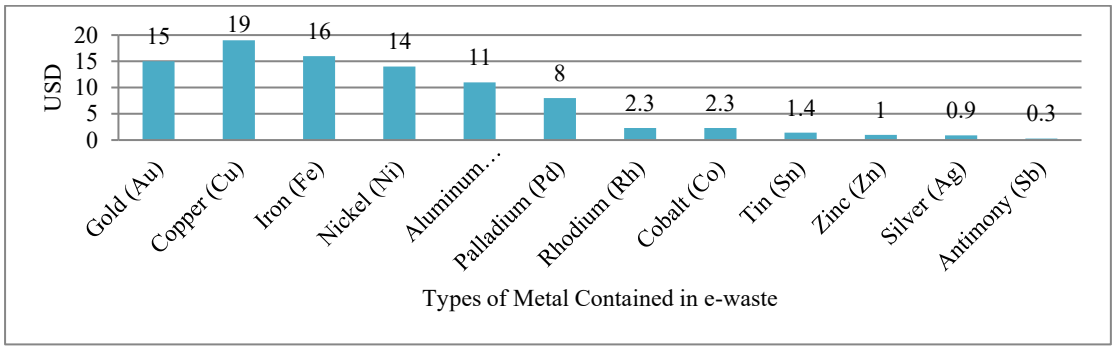

Chart 07: Global gross value of the metals contained in e-waste, 2022

Metals	Recycling Rate (%)	Different Used
Gold	86	Jewelry / Electronics
Platinum/Palladium	60	Optical fibers / Dental fillings
Nickel	60	Batteries / Turbine blades
Silver	50	Jewelry / Mirrors
Copper	46	Electrical wiring / Industrial equipment
Aluminum	42	Aeroplane parts / Cans
Chromium	34	Stainless steel / Leather tanning
Zinc	33	Galvanizing metal / Making rubber
Cobalt	32	Batteries / Turbine engines
Lithium	0.5	Batteries / Pacemakers
REEs	0.2	Mobile phones / Hard drives

Table 04: Global recycling rates of metals, 2021

The Table-04 provides information on the various uses of recycled metals. The recycling rate of gold is 86%, and from 1995 to 2014, one-third of the total gold supply came from recycling, according to the Boston Consulting Group. While widely used metals like steel and valuable ones like gold have high recycling rates, rare earth elements in electronics are harder to recycle. The end-of-life recycling rate often depends on the weakest link in the recycling chain related to collection methods, with economic incentives driving businesses toward higher financial returns, sometimes overlooking other areas.

XI. PROBABLE WAYS TO MANAGE E-WASTES IN BANGLADESH

Managing e-waste in Bangladesh requires a comprehensive and multi-faceted approach that addresses the unique challenges posed by rapid urbanization, increasing electronics consumption, and a largely informal recycling sector. Effective management strategies must combine regulatory enforcement, infrastructure development, public awareness, and stakeholder collaboration to minimize environmental and health risks. By adopting sustainable practices such as formalizing collection systems, promoting repair and reuse, regulating imports, and encouraging innovation, Bangladesh can move toward a circular economy that reduces e-waste generation and maximizes resource recovery. In fig.-03, trying to provide a conceptual framework.

Stablish Formal E-Waste Collection & Recycling Infrastructure
Implement and Enforce Extended Producer Responsibility (EPR)
Promote Repair, Refurbishment, and Reuse
Regulate the Import and Sale of Second-Hand Electronics
Raise Public Awareness and Behavioral Change
Formalize the Informal Sector
Develop a National E-Waste Inventory and Data System
Offer Incentives and Subsidies for Green Business Models
Establish Clear Legal and Institutional Frameworks
Encourage Academic and Industry Research

Figure 04: Probable ways to manage e-wastes in Bangladesh

Establish Formal E-Waste Collection & Recycling Infrastructure: To effectively manage e-waste in Bangladesh, it is crucial to establish certified, environmentally sound recycling facilities in major urban centers. A nationwide network of authorized collection centers should be developed to collect e-waste from households, offices, retailers, and institutions. These centers must be easily accessible and properly equipped. Public-private partnerships (PPPs) can play a vital role in scaling up infrastructure by leveraging government support and private sector innovation, funding, and technical expertise. This formal system would help shift e-waste away from the informal sector and ensure safe and sustainable processing.

Implement and Enforce Extended Producer Responsibility (EPR): Implementing Extended Producer Responsibility (EPR) is essential to hold producers and importers accountable for the end-of-life management of electronic products. Under this approach, companies should be mandated to collect and recycle a defined percentage of the electronics they sell. The existing 2021 E-Waste Management Guidelines must be actively enforced through regular monitoring, reporting requirements, and strict penalties for non-compliance. Additionally, manufacturers should be encouraged to invest in recycling infrastructure and public awareness campaigns as part of their corporate responsibility and compliance strategy.

Promote Repair, Refurbishment, and Reuse: Promoting repair, refurbishment, and reuse is a key strategy to extend the lifespan of electronic products and reduce e-waste generation. Local repair shops should be supported through training programs and certifications to ensure safety, technical quality, and consumer trust. Incentives such as tax benefits or low-interest loans can be introduced to boost the market for refurbished electronics. Furthermore, implementing "Right to Repair" policies will require manufacturers to provide spare parts, tools, and manuals, empowering consumers and small businesses to repair devices instead of discarding them prematurely.

Regulate the Import and Sale of Second-Hand Electronics: Regulating the import and sale of second-hand electronics is essential to prevent Bangladesh from becoming a dumping ground for near-end-of-life electronic products. Quality control standards must be enforced to ensure that imported used electronics are safe, functional, and have a reasonable lifespan. Stricter customs inspections and documentation requirements should be implemented to curb the illegal entry of e-waste disguised as second-hand goods. Additionally, regional collaboration with neighboring countries like India and ASEAN members is crucial to monitor and control cross-border movements of e-waste effectively.

Raise Public Awareness and Behavioral Change: Raising public awareness is critical for changing attitudes and behaviors toward e-waste disposal in Bangladesh. Nationwide campaigns should be launched to educate citizens about the environmental and health hazards of improper e-waste handling, along with promoting safe and responsible alternatives. E-waste education can be integrated into school curricula to build awareness from a young age. Additionally, leveraging digital platforms, social media, and community-based programs can effectively engage the public and encourage greater participation in formal e-waste collection and recycling efforts.

Formalize the Informal Sector: Formalizing the informal e-waste sector is vital to improving health, safety, and environmental outcomes. Informal collectors and dismantlers should be trained and integrated into the formal waste management system, equipping them with personal protective equipment (PPE), safe tools, and access to buy-back incentives. Recognizing their important role as primary collectors, these workers can be linked to certified recyclers, creating a more efficient and responsible e-waste value chain that benefit both the environment and the community.

Develop a National E-Waste Inventory and Data System: Developing a comprehensive national e-waste inventory and data system is essential for effective management. This involves creating a centralized, regularly updated database that tracks e-waste generation, collection, and recycling activities across the country. Utilizing GIS mapping and digital tracking technologies can help visualize waste flows and identify hotspots. Reliable data will enable policymakers and stakeholders to make informed, evidence-based decisions, improve regulations, and monitor progress toward sustainable e-waste management goals.

Offer Incentives and Subsidies for Green Business Models: To encourage sustainable e-waste management, the government should provide tax rebates and soft loans to entrepreneurs engaged in recycling, up cycling, and reverse logistics. Prioritizing government procurement of electronics made with recycled materials can create a steady demand for green products. Additionally, supporting startups and innovations in advanced e-waste technologies, such as urban mining and automation, will foster a competitive and environmentally friendly industry that drives Bangladesh toward a circular economy.

Establish Clear Legal and Institutional Frameworks: Strengthening Bangladesh's e-waste management requires clear legal and institutional frameworks with well-defined roles among ministries such as Environment, ICT, and Industry. Mandatory registration and licensing of recyclers will help regulate the sector and ensure compliance with environmental standards. Introducing strict penalties for illegal dumping, open burning, and unlicensed operations will deter harmful practices and promote accountability, creating a safer and more sustainable e-waste management system.

Encourage Academic and Industry Research: Encouraging research on e-waste management is crucial for developing effective, locally adapted solutions. Funding should be directed toward studies on materials recovery, toxic waste treatment, and lifecycle analysis of electronic products. Universities and research institutes can play a key role by participating in pilot projects and facilitating technology transfer. Strengthening collaboration between academia and industry will foster innovation, enabling Bangladesh to address its e-waste challenges with homegrown technologies and sustainable practices.

XII. RECYCLING PROCESS OF E-WASTE

Recycling or donating our used electronics is a great way to reduce waste and protect the environment. However, it is essential to understand that taking our e-waste down to the local recycling center is not a guarantee that it will get recycled correctly. The e-waste recycling process is labor-intensive and involves several steps. In Figur-04, providing a systematic breakdown of how the e-waste recycling process works:

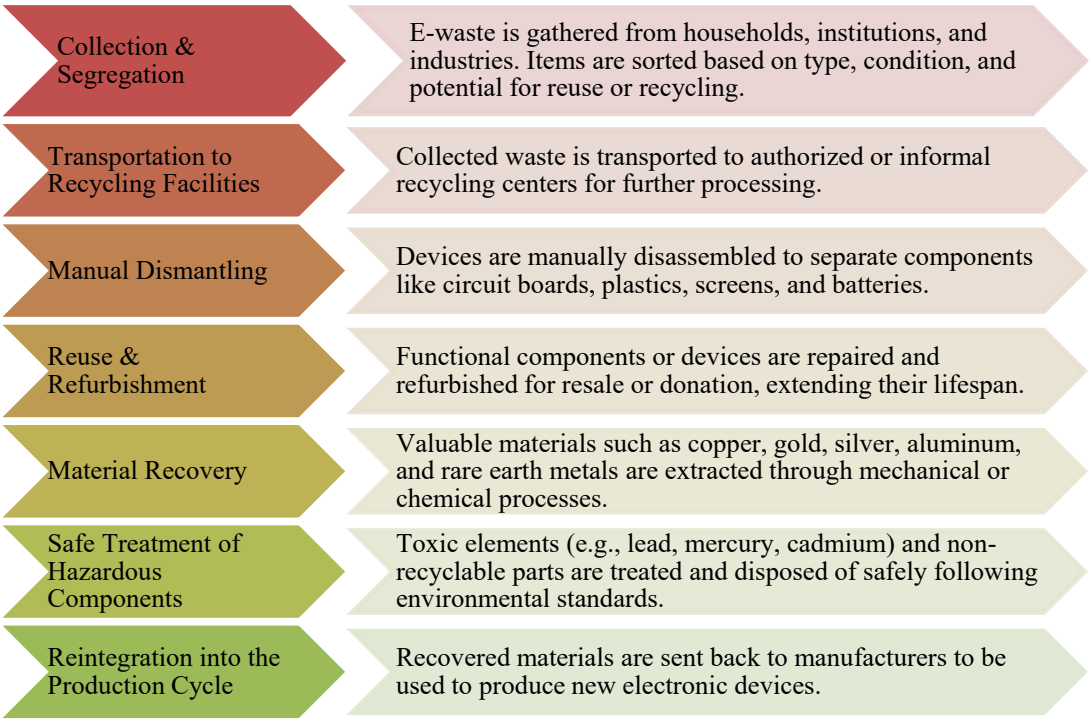
Collection & Segregation
E-waste is gathered from households, institutions, and industries. Items are sorted based on type, condition, and potential for reuse or recycling.
Transportation to Recycling Facilities
Collected waste is transported to authorized or informal recycling centers for further processing.
Manual Dismantling
Devices are manually disassembled to separate components like circuit boards, plastics, screens, and batteries.
Reuse & Refurbishment
Functional components or devices are repaired and refurbished for resale or donation, extending their lifespan.
Material Recovery
Valuable materials such as copper, gold, silver, aluminum, and rare earth metals are extracted through mechanical or chemical processes.
Safe Treatment of Hazardous Components
Toxic elements (e.g., lead, mercury, cadmium) and non-recyclable parts are treated and disposed of safely following environmental standards.
Reintegration into the Production Cycle
Recovered materials are sent back to manufacturers to be used to produce new electronic devices.

Figure 05: Recycling Process of E-waste

XIII. ECONOMIC BENEFITS OF E-WASTE RECYCLING

The amount of electronic waste or e-waste produced globally each year exceeds 50 metric tons and is increasing daily as technology rapidly advances. E-waste includes items such as computers, laptops, televisions, and mobile phones, most of which can be easily processed for reuse or to extract materials. This process is known as e-waste recycling, which provides a number of economic benefits.

Resource of Employment: Recycling e-waste is a crucial process that not only safeguards the environment from hazardous substances but also has a positive impact on the economy by generating new jobs. Recycling procedures necessitate a significant amount of work force, which creates ample employment opportunities for skilled individuals and reduces the amount of time and resources required to manufacture new products.

Cost Minimization: E-waste is often disposed of in landfills without proper recycling procedures, which is insufficient in our country. Consequently, the scrap materials have to be sent abroad to landfills, incurring significant costs for transportation and management. Establishing domestic e-waste recycling services will not only save costs but also alleviate the pressure on foreign countries where the waste was previously sent. Additionally, other countries can choose to send their e-waste to our country for recycling, thereby enabling us to earn foreign exchange.

Economic Incentives: Global environmental groups are putting pressure on electronics manufacturers to take responsibility for e-waste. In response, many manufacturers offer financial incentives to recycling facilities that handle old electronic products in bulk. This also helps to reduce raw material costs for manufacturers, which results in more affordable prices for consumers, ultimately improving the average standard of living. Therefore, it is a win-win situation for both manufacturers and consumers.

Reserve Preservation: Recycling e-waste provides manufacturers with valuable resources that support sustainable development while also easing the burden on a country's economy. It significantly reduces extraction costs by eliminating the need for mining and processing of raw materials and minerals.

Energy Efficiency: E-waste recycling is a much more energy-efficient process compared to raw material mining, and it costs less than what is needed to extract them from the Earth's crust. This leads to less pollution and creates less dependence on already scarce minerals, making it an eco-friendly solution.

Provides good business opportunities: E-waste recycling provides a great business opportunity in our country. Currently, there are not many e-waste recycling facilities available globally. By starting a facility in your city, you can reap the benefits of incentives and raw materials, making it a lucrative initiative. This is especially true for developing countries, where these recycling processes are more vibrant due to the availability of resources and workers. Thus, e-waste recycling is a great initiative that is bound to prosper, and starting it in a developing country can prove to be a wise decision.

Possibility of Research: There is also huge room for improvement in e-waste development. It provides a hopeful topic for industrial and environmental research. Many new projects are likely to be concerned with developing well-organized and more cost-effective recycling processes. This will require both money and intelligence, which is clear to make stronger the nationwide economy.

Current scenario in Bangladesh: Presently in Bangladesh, recycling of unnecessary electronic goods is mostly carried out by the informal sector. Electronic wastes are collected, segregated, dismantled and recycled in the familiar sector based in the metropolitan slums of Dhaka. According to NBR data, over the last three years, 63,003,818 mobile phones have entered Bangladesh. However, the maximum lifetime of a mobile phone is presently only 2.5 years or less in some cases. This means that in the upcoming two to three years, these used mobile phones and unaccounted informal imports will be added to Bangladesh's waste stream. As our nation moves towards digitization, the use of electı
expected to increase rapidly. The next players in the trade value chain are informal scrap collectors or *Vangariwalas (local Bengali term)*, who purchase e-waste directly from users. In Photo-02, giving a real photograph of a *Vangariwala* in Bangladesh.

The *Vangariwalas* then sell it in the second-hand market, repair and sell to consumers or second-hand shops, or sell to bulk collectors and manual dismantlers. Once the devices are dismantled, their various components are sent to different locations around Dhaka for further processing, recycling and smelting operations. The final step in the value chain is recycling, during which precious and specialty metals are extracted from the material. However, manual dismantling and recycling stages include processes such as open burning and acid treatment, which can be harmful to the environment and human health.

Photo 02: Current e-waste Business scenario in Bangladesh

XIV. RECOMMENDATIONS FOR SUSTAINABLE E-WASTE MANAGEMENT IN BANGLADESH

Strengthen Policy and Regulatory Framework To ensure effective management of electronic waste in Bangladesh, it is crucial to strictly enforce the E-Waste Management Rules 2021 through consistent monitoring, penalties, and regular inspections. A comprehensive National E-Waste Policy Framework should be developed to bring all stakeholders under a unified and coordinated action plan. Clear guidelines must be established for producers and importers under the Extended Producer Responsibility (EPR) model to ensure accountability throughout the product lifecycle. Additionally, harmonizing the roles and responsibilities of key government agencies such as the Department of Environment (DoE), Ministry of ICT (MoICT), BTRC, and City Corporations is essential to avoid overlap and ensure smooth implementation of e-waste policies.

Formalize and Regulate the Informal Sector

To improve e-waste management and promote social inclusion, it is essential to integrate informal recyclers into the formal system through proper registration, capacity-building training, and financial incentives. Establishing cooperative platforms can enable informal collectors and dismantlers to work safely within a regulated environment, ensuring both environmental and occupational safety. Moreover, providing access to protective gear, appropriate tools, and training in environmentally sound recycling practices will enhance efficiency and reduce health and ecological risks associated with informal e-waste handling.

Establish E-Waste Collection and Recycling Infrastructure

To build an efficient e-waste management infrastructure, it is vital to establish nationwide e-waste collection points, particularly in major urban centers such as Dhaka, Chattogram, and Khulna, where electronic waste generation is highest. Investment should be directed toward developing environmentally compliant recycling and material recovery facilities that can process e-waste safely and efficiently. Additionally, promoting public-private partnerships (PPPs) will help attract investment, foster innovation, and ensure the sustainable development of the e-waste management sector across the country.

Enhance Public Awareness and Behavioral Change

Raising public awareness is key to the success of e-waste management efforts in Bangladesh. National campaigns should be launched to educate citizens about the health hazards and environmental risks associated with improper e-waste disposal. Integrating circular economy principles and recycling culture into school and university curricula can foster long-term behavioral change among younger generations. Furthermore, encouraging consumer participation through take-back programs and offering incentives such as discounts for returning old electronic devices can significantly boost responsible e-waste disposal practices.

Promote Research, Data and Innovation

Advancing knowledge and innovation is essential for sustainable e-waste management in Bangladesh. Supporting academic and institutional research on e-waste quantification, life cycle analysis, and its health impacts will provide critical data for informed policy-making. Establishing a national database and tracking system for monitoring e-waste flows and recycling performance will enhance transparency and accountability. Additionally, promoting innovation in eco-design, modular electronics, and green recycling technologies can reduce environmental harm and foster a more sustainable electronics industry.

Develop Economic Incentives

To stimulate private sector involvement in e-waste management, the government should offer tax incentives and low-interest loans to companies investing in e-waste collection, recycling, and recovery initiatives. Introducing a deposit-refund system for electronic purchases can encourage consumers to return used devices responsibly, fostering a culture of reuse and recycling. Moreover, supporting small and medium enterprises (SMEs) engaged in green technology and circular economy solutions will not only drive innovation but also create green jobs and strengthen the overall sustainability of the e-waste management ecosystem.

Regional and International Cooperation

International collaboration is vital for enhancing Bangladesh's capacity to manage e-waste effectively. Collaborating with regional stakeholders and global e-waste alliances can facilitate knowledge exchange, technology transfer, and access to international funding opportunities. Additionally, strict compliance with global agreements such as the Basel Convention is essential to prevent the illegal transboundary movement of hazardous e-waste and to uphold environmental and public health standards in line with international best practices.

Foster Innovation and Research:

Collaboration among governments, educational institutions, research organizations, and industry is vital. Securing funding and applying research practically are key for the sustainable recycling of electronic waste, plastics, and construction debris. Supporting green startups and fostering partnerships between universities and industry can boost local expertise and innovation. Ultimately, a commitment to research and innovation is essential for protecting the environment and promoting sustainability.

Incentivize Green Business Models:

To promote sustainable e-waste management, governments should offer tax breaks and subsidies to startups adopting green business models. These incentives can lower initial investment and operational costs, making it easier for businesses to implement eco-friendly recycling and disposal methods. This not only reduces environmental pollution but also fosters innovation, attracting more companies to participate in responsible e-waste management and creating jobs in the green sector, contributing to a circular economy.

Develop Robust Data Systems:

Establish a comprehensive nationwide electronic waste inventory that employs advanced digital tools and Geographic Information Systems (GIS) to meticulously monitor the generation, movement, and processing of electronic waste. This initiative will serve as a robust foundation for data-driven policymaking, ensuring that decisions are guided by accurate and current information concerning the management of electronic waste. By integrating these technologies, we can enhance our understanding of e-waste flows, identify critical trends, and develop effective strategies for sustainable treatment and recycling.

Implement Extended Producer Responsibility (EPR):

Establish a comprehensive framework that holds producers and importers accountable for the entire lifecycle of their products. This initiative should mandate that these entities actively participate in the management of their products, which includes the implementation of systems for take-back and recycling. By doing so, they will not only reduce waste but also foster a more sustainable environment by ensuring that materials are effectively reused and repurposed following the initial use of the product.

XV. CONCLUSION

Electronic waste has emerged as a significant environmental and socio-economic challenge in Bangladesh, driven by the accelerated adoption of digital methods, widespread informal recycling practices, and inadequate regulatory oversight. This study critically examines the conceptual and functional dimensions of e-waste, highlighting its multifaceted impact on public health, environmental integrity, and urban sustainability. Despite the enactment of the E-Waste Management Regulations 2021, significant barriers remain, including weak institutional enforcement, fragmented stakeholder coordination, limited public awareness, and a lack of formal recycling infrastructure. Addressing these systemic gaps requires a coordinated, multi-stakeholder response that integrates policy reforms, gradual formalization of the informal sector, targeted investments in green infrastructure, and advancement of public education and research-led innovation. If used effectively, e-waste can be transformed from an unmanaged burden into a resource-rich opportunity, supporting circular value chains, creating green jobs, and advancing Bangladesh's commitment to sustainable development. By aligning national action with global sustainability frameworks such as the Sustainable Development Goals (SDGs), especially Goal 12 on responsible consumption and production, Bangladesh can pave the way towards a more resilient, inclusive, and circular economic future.

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AUTHOR BIOGRAPHY

Md. Mahamudur Rahman (Papon) is a multidisciplinary professional with extensive expertise in eco-friendly architectural design, environmental sustainability, disaster management, policy analysis, and strategic management. He currently serves as the Principal Architect and Environmentalist at *Eco Design Consultants Bangladesh (EDCBD)*, where he leads initiatives focused on sustainable design and climate-resilient development.

Mr. Rahman holds two master's degrees - MS in Environmental Science from the *State University of Bangladesh* and MS in Disaster Management from the *University of Dhaka*, which underpins his strong academic foundation in both environmental and disaster management fields. In addition, he has completed Professional training in Policy Analysis and Strategic Management at the *Bangladesh Institute of Governance and Management (BIGM)* under the SEIP project, equipping him with valuable skills in public policy and institutional strategy.

With a professional background that spans the Architecture, Environment, and Disaster Risk Reduction (DRR) sectors, Mr. Rahman is also an experienced researcher and practitioner. He has previously held key positions including Project Architect at the *Department of Architecture under the Ministry of Housing and Public Works* and Project Coordinator/Jr. Architect at *Parikalpak Consultants Ltd.* His multidisciplinary approach has made significant contributions to environmentally responsible planning, sustainable infrastructure, and resilience-building projects in Bangladesh.

He is currently the General Secretary of the Institute of Environmentalists, Bangladesh (BIE) and an active member of several professional bodies. Mr. Rahman is a Member of the Institute of Architects Bangladesh (IAB) and has previously served on the Environment & Urbanization Committee (24th, 25th, & 26th EC) of the IAB and the Tours & Travel Committee, ARCASIA, hosted by IAB.

Born and based in Dhaka, Bangladesh, Md. Mahamudur Rahman (Papon) continues to advocate for integrated solutions at the intersection of architecture, environment, and policy to promote a sustainable and climate-resilient future for Bangladesh.